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# Astronomy algorithm simulation for two degrees of freedom of solar tracking mechanism using Clanguage

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**Abstract**

This paper describes the use of an astronomical algorithm for two degrees of freedom of solar tracking mechanism with the result that the expected solar thermal collector panels always leads to the sun and solar energy is absorbed optimally. The movement triggers of the sun tracking mechanism is an astronomical algorithm that generates the azimuth and altitude values based on latitude, longitude, and time. This system does not use any sensor so that is more economical and can be applied anywhere. Simulations have been made using the C programming language with Dev-C++ IDE to test the accuracy of the azimuth and elevation values generated by astronomical algorithm used, and compared with the value produced by the U.S. Naval Observatory and Geoscience Australia. The location used is LIPI Bandung with latitude 107°36'E and longitude 6°52'S at every hour from 06:00 to 18:00 on the first date of each month of 2013. Simulation results show that the value of the azimuth and elevation resulting approached two other reference values with maximum azimuth difference 0.51 degrees and the maximum altitude difference 0.49 degrees to data the U.S. Naval Observatory, and the maximum azimuth difference 0.52 degrees and the maximum altitude difference 0.50 degrees to the data Australia Geoscience. Based on this research, it is known that the azimuth and elevation values was generated by these algorithms can be applied to two degrees of freedom of solar tracking mechanism because its accuracy is close to two other reference values.


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*Keywords:* two degrees of freedom of solar tracking mechanism; astronomy algorithm; azimuth; altitude; c programming language

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## 1. Introduction

Solar thermal energy is one of the main potential sources of renewable energy to be utilized, including the Indonesian region [1]. Solar tracking mechanism is required in order to optimally absorption of photovoltaic panels and concentrated solar panels so the panel always toward the sun. Solar tracking mechanism control system of one degree of freedom have been reported by Midriem et.al [2-3], but to obtain more optimal solar energy needed two degrees of freedom of solar tracking mechanism (azimuth and altitude). The efficiency of solar energy absorption using one degree of freedom of solar tracking mechanism can be increased 27-32% rather than a fixed panel position at the optimum angle, while the efficiency of solar energy absorption using two degrees of freedom of solar tracking mechanism are better 35-40% than a fixed panel position at the optimum angle, or increased about 6% from one degrees of freedom of solar tracking mechanism [4]. One of the main problems using mechanism of two degrees of freedom is the complexity and expensive cost [5]. This paper describes the use of astronomical algorithms to be applied for two degrees of freedom of solar tracking mechanism. The triggers panel movement is an astronomical algorithm that generates azimuth and elevation angles, without using any sensors so that is easier, cheaper, and can be applied in the anywhere location simply by changing latitude, longitude, and time zone of the panel location.

Simulations have been made using the C programming language with Dev-C++ IDE [6] to test the accuracy of the azimuth and elevation angle produced by the astronomy algorithm used. Azimuth and altitude obtained then compared with the values obtained from the calculation of U.S. Naval Observatory [7] and Geoscience Australia [8]. The location used is LIPI Bandung with latitude 107°36’E and longitude 6°52’S [9] at every hour from 06:00 to 18:00, on first date in every month of 2013.

## 2. Methodology

The astronomical algorithm used in this paper based on Rinto [10]. This algorithm generates the azimuth and altitude anglebased on the input coordinates i.e. latitude, longitude, and time zone [11], time (date, month, year, hours, minutes, and seconds). Based on the azimuth and altitudeangle, it can be seen the position of the sun [7]. Preview the azimuth and altitude of the sun can be seen in Fig. 1.

Azimuth is the angle along the horizon, with zero degrees pointing toward the north, and increases clockwise, so 90 degrees pointing to the east, 180 degrees pointing to the south, and 270 degrees pointing to the west. Altitude is the angle up from the horizon. Zero degrees altitude means the appropriate position in the local horizon, 90 degrees means straight up or the angle is 90 degrees up from the horizon, and -90 degrees means straight down or the angle is -90 degrees below the horizon.

The algorithm requires data input such as latitude, longitude, time zone, date, month, year, hours, minutes, and seconds, so it will generate the azimuth and altitude angle that can be used as a reference position of the sun at the time entered. The latitude and longitude were adjusted to place of the panel. The input date, month, and year calendar customized with AD, while the hours, minutes, and seconds using 24 hours’ time format. This algorithm can be applied to a processor or microcontroller i.e. ATMega8535. The program has been created using C language with Dev-C++ IDE to implement the algorithm as shown in Fig. 2, while flowchart of this astronomical algorithm can be seen in Fig. 3.

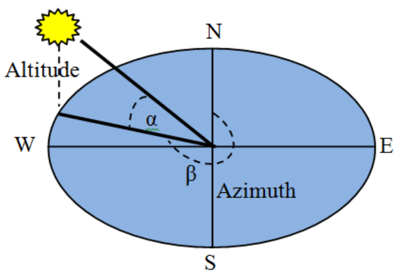



Fig. 1. Preview of the azimuth and altitude of the sun.

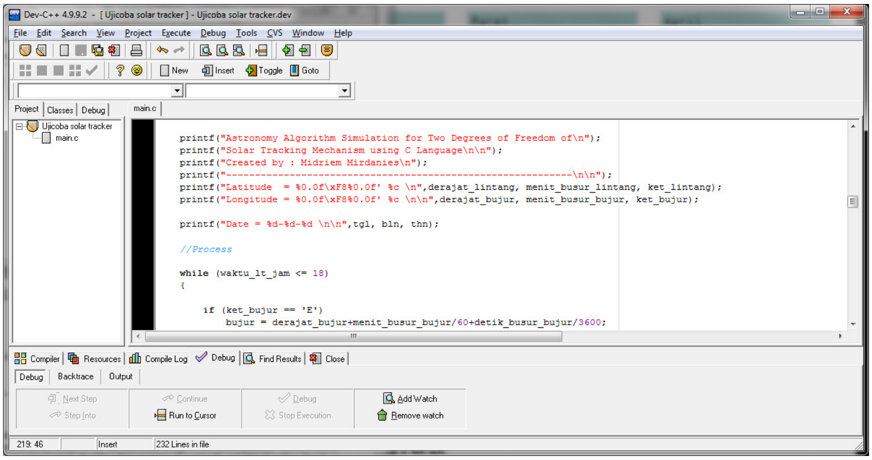



Fig. 2. Simulation using Dev-C++IDE.

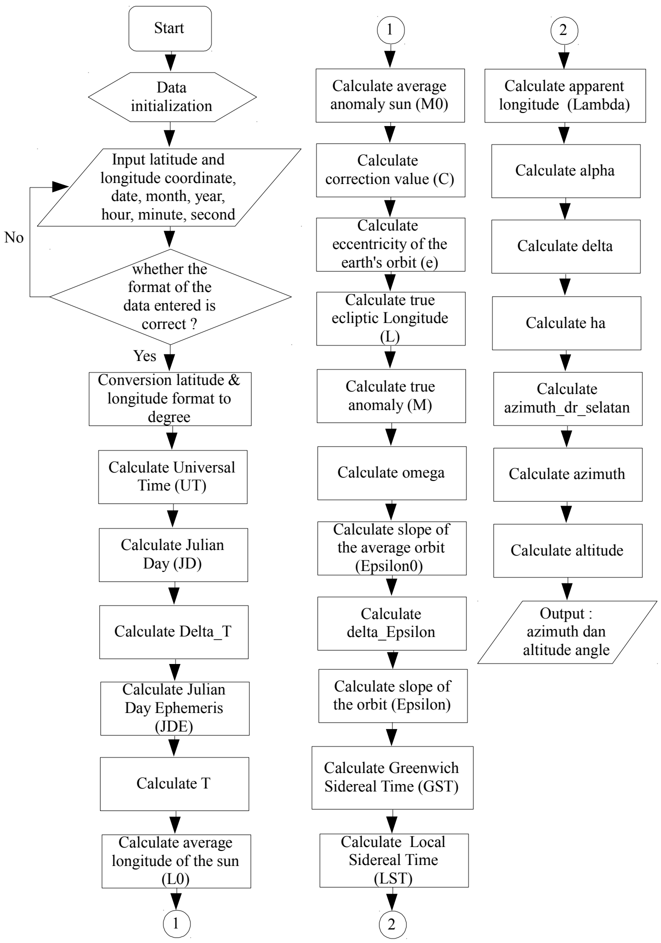



Fig. 3. Calculation of azimuth and altitude angle.

## 3. Result and discussion

The simulation program that has been created can be seen in Fig. 4. After the value of latitude, longitude, time zone, date, month, and year entered, then the program will display the value of the azimuth and elevation angle at every hour from 06:00 to 18:00. This is repeated 12 times every first date of the month from January to December in 2013. Azimuth angle were obtained can be seen in Fig. 5, while elevation angle can be seen in Fig. 6.

Azimuth and elevation angle obtained from the simulation results compared with the values obtained from the U.S. Naval Observatory and Geoscience Australia at the same time and coordinates. Azimuth and elevation angle obtained from the U.S. Naval Observatory can be seen in Fig. 7a and Fig. 7b. Azimuth and elevation angle values obtained from Geoscience Australia can be seen in Fig. 8a and Fig. 8b.

In Fig. 5 and Fig. 6 it can be seen that in general, the azimuth and elevation angle of the resulting algorithm were generally similar to the results obtained from the U.S. Naval Observatory (Fig. 7) and Geoscience Australia (Fig. 8). The maximum azimuth difference compared to the data from Geoscience Australia occurred on 01-02-2013 07:00 = 0.52 degrees, and the maximum azimuth difference compared with data U.S. Naval Observatory occurred on 01-02-2013 07:00 = 0.51 degrees. This can be seen in the circled value with dotted lines in Table 1.

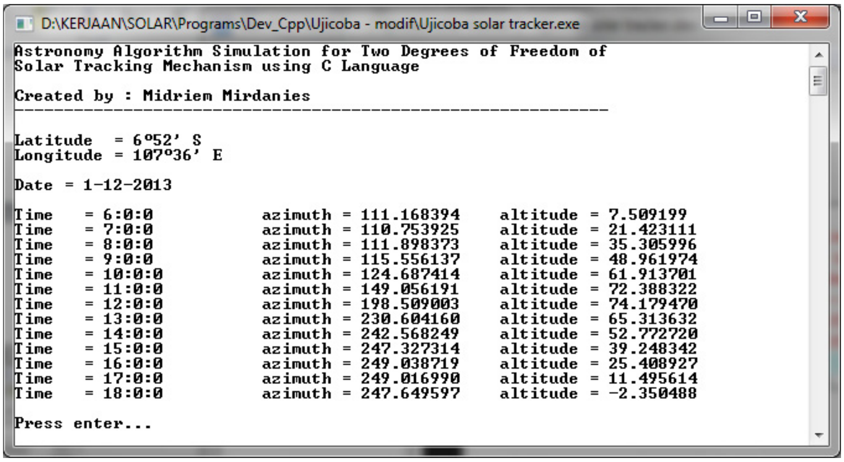



Fig. 4. Display simulation program.

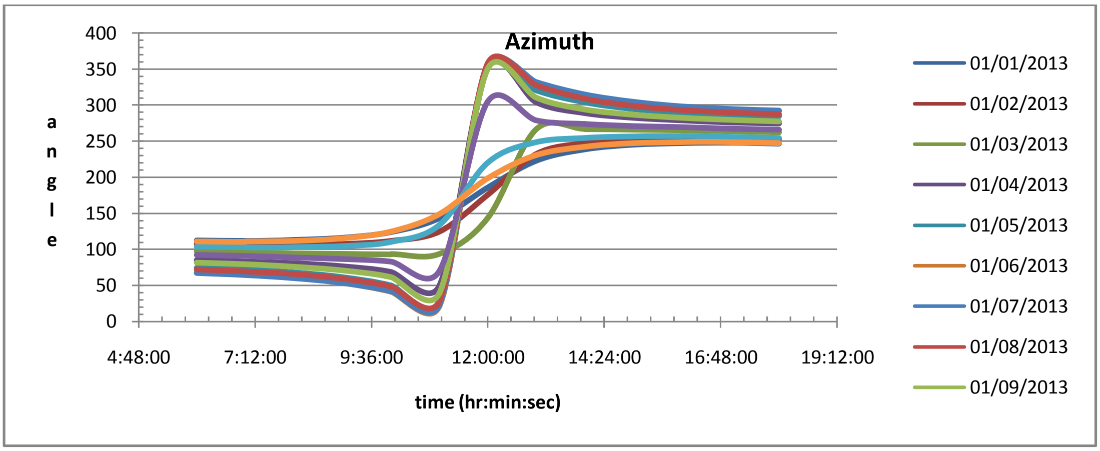



Fig. 5. Azimuth angle at 06:00 to 18:00 on first day in every month of 2013.

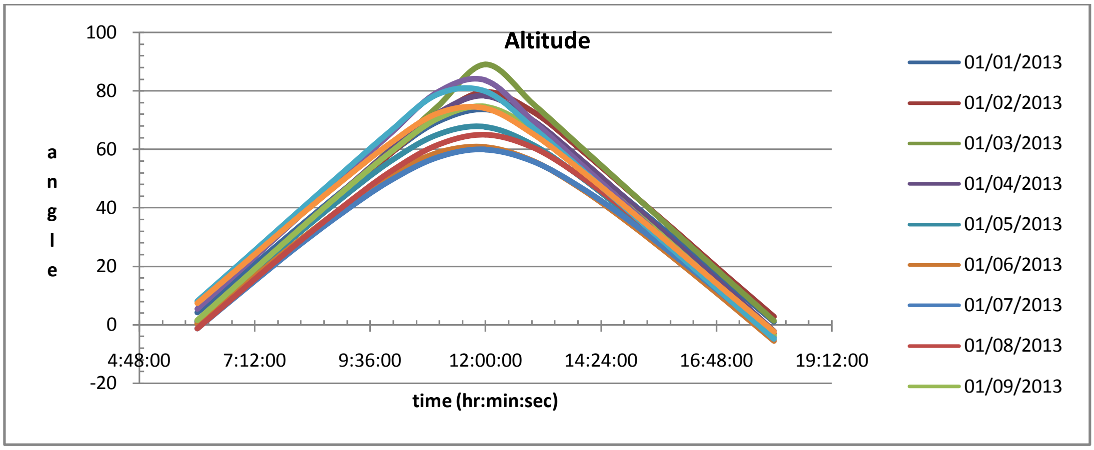
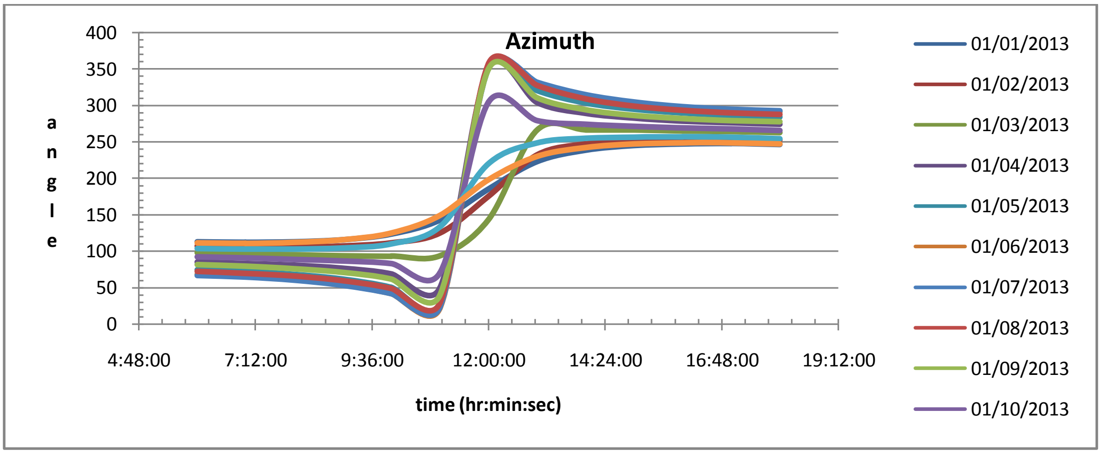
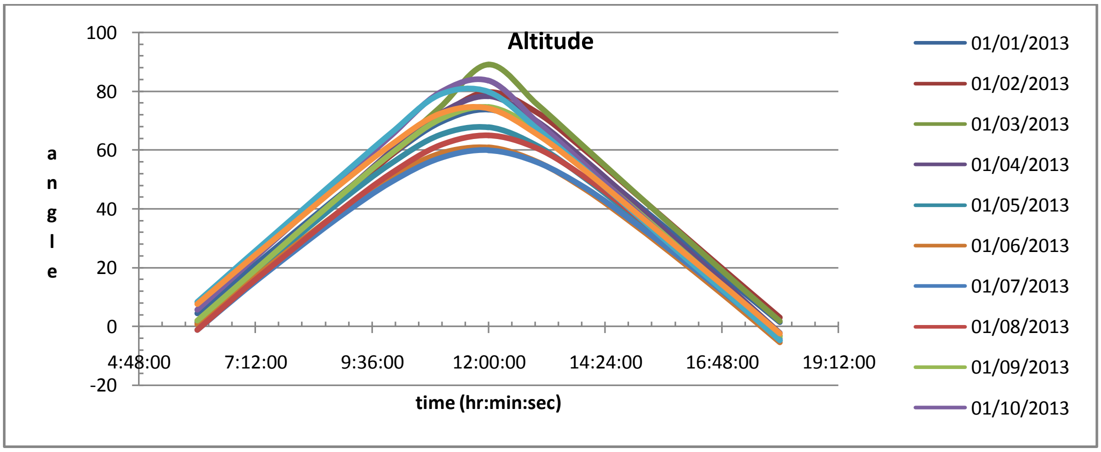



Fig. 6. Altitude angle at6:00 to 18:00on first day in every month of 2013.

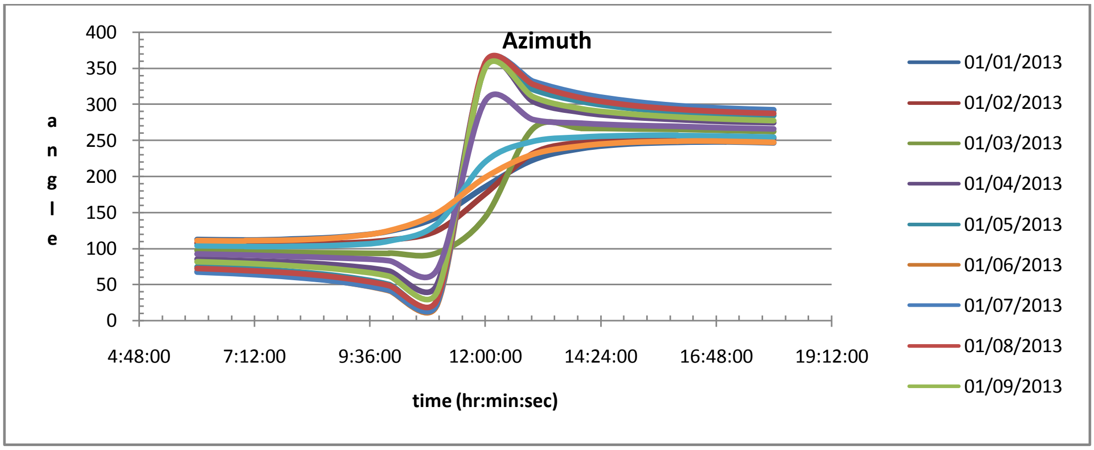



(a)

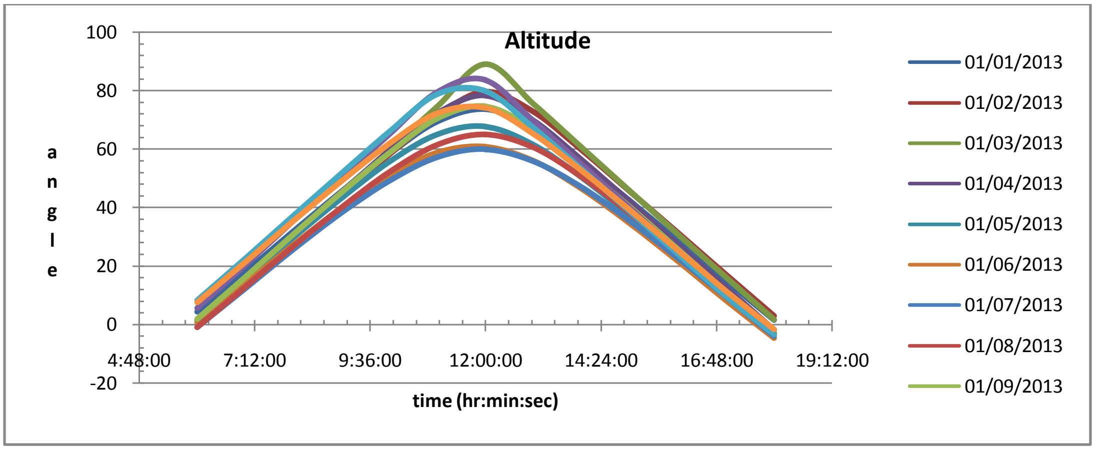



(b)

Fig. 7. Value; (a) azimuth and; (b) altitude angle at 6:00 to 18:00 on first date in every month of 2013 based on data from the U.S. Naval Observatory.




(a)




(b)

Fig. 8. Value; (a)azimuth and; (b) altitude angle at 6:00 to 18:00 on first date in every month of 2013 based on data from Geoscience Australia.

Maximum altitude difference compared with the data from Geoscience Australia occurred on 01-06-2013 06:00 = 0.50 degrees, and the maximum altitude difference compared with data U.S. Naval Observatory occurred on 01-03-2013 06:00 = 0.49 degrees. This can be seen in the circled value with dotted lines in Table 2 and Table 3. From the simulation results it is known that the azimuth and elevation angle produced by these algorithms approach the data produced by Geoscience Australia and the U.S. Naval Observatory.

Table 1. Azimuth angle on 01-02-2013 using the proposed algorithm, the data from the Geoscience Australia, and the U.S. Naval Observatory

| Time | Propose algorithm | Geoscience Australia | U.S. Naval Observatory |
|---|---|---|---|
| 6:00:00 | 107.09 | 107.09 | 107.10 |
| 7:00:00 | **105.39** | **105.91** | **105.90** |
| 8:00:00 | 105.81 | 105.80 | 105.80 |
| 9:00:00 | 107.20 | 107.19 | 107.20 |
| 10:00:00 | 111.56 | 111.56 | 111.60 |
| 11:00:00 | 124.88 | 124.87 | 124.90 |
| 12:00:00 | 175.71 | 175.70 | 175.70 |
| 13:00:00 | 232.48 | 232.48 | 232.50 |
| 14:00:00 | 247.74 | 247.74 | 247.70 |
| 15:00:00 | 252.63 | 252.63 | 252.60 |
| 16:00:00 | 254.24 | 254.24 | 254.20 |
| 17:00:00 | 254.28 | 254.28 | 254.30 |
| 18:00:00 | 253.22 | 253.22 | 253.20 |

Table 2. Elevation angle on 01-06-2013 using the proposed algorithms, and data from the Geoscience Australia

| Time | Propose algorithm | Geoscience Australia |
|---|---|---|
| 6:00:00 | **0.33** | **0.83** |
| 7:00:00 | 13.99 | 14.05 |
| 8:00:00 | 27.28 | 27.30 |
| 9:00:00 | 39.83 | 39.84 |
| 10:00:00 | 50.89 | 50.90 |
| 11:00:00 | 58.82 | 58.83 |
| 12:00:00 | 60.90 | 60.90 |
| 13:00:00 | 56.03 | 56.04 |
| 14:00:00 | 46.50 | 46.52 |
| 15:00:00 | 34.68 | 34.70 |
| 16:00:00 | 21.76 | 21.80 |
| 17:00:00 | 8.29 | 8.39 |
| 18:00:00 | -5.47 | -5.47 |

Table 3. Elevation angle on 01-03-2013 using the proposed algorithms, and data from the U.S. Naval Observatory

| Time | Propose algorithm | U.S. Naval Observatory |
|---|---|---|
| 6:00:00 | **0.41** | **0.90** |
| 7:00:00 | 15.20 | 15.30 |
| 8:00:00 | 30.03 | 30.10 |
| 9:00:00 | 44.88 | 44.90 |
| 10:00:00 | 59.74 | 59.80 |
| 11:00:00 | 74.61 | 74.60 |
| 12:00:00 | 89.18 | 89.20 |
| 13:00:00 | 75.59 | 75.60 |
| 14:00:00 | 60.72 | 60.70 |
| 15:00:00 | 45.85 | 45.90 |
| 16:00:00 | 30.99 | 31.00 |
| 17:00:00 | 16.16 | 16.20 |
| 18:00:00 | 1.36 | 1.70 |

## 4. Conclusion

The use of astronomy algorithms for solar tracking mechanism two degrees of freedom based on the value of the azimuth and altitude resulting has been discussed. Inputs to the algorithm is latitude, longitude, time zone, date, month, year, hours, minutes, and seconds. Simulations have been made to generate the azimuth and altitude angle at LIPI Bandung with latitude 107°36'E and longitude 6°52'S at every hour from 06:00 to 18:00 on first date in every month of 2013. Simulation results show that the azimuth and elevation resulting approached two other reference values with maximum azimuth difference = 0.51 degrees and the maximum altitude difference = 0.49 degrees to data the U.S. Naval Observatory, and the maximum azimuth difference = 0.52 degrees and the maximum altitude difference = 0.50 degrees to the data Australia Geoscience. Based on this research, it is known that this algorithm can be applied to two degrees of freedom of solar tracking mechanism because its accuracy is very similar to other reference values.

## References


[1] M. H. Hasan, T. Mahlia and H. Nur, "A Review on Energy Scenario and Sustainable Energy in Indonesia," Renewable and Sustainable Energy Reviews, no. 16, pp. 2316-2328, 2012.

[2] M. Mirdanies, R. A. Ardiansyah, H. M. Saputra, A. S. Nugraha, E. Rijanto and A. Santoso, "Rancang Bangun Sistem Kontrol Mekanisme Pelacakan Matahari Beserta Fasilitas Telekontrol Hemat Energi," Journal of Mechatronics, Electrical Power, and Vehicular Technology , vol. 02, pp. 31-40, July 2011.

[3] M. Mirdanies and R. P. Saputra, "Sistem Kontrol Mekanisme Pelacakan Matahari Menggunakan Kombinasi Algoritma Astronomi dan Sensor Cahaya," in Seminar Nasional Rekayasa Energi, Mekatronik, dan Teknik Kendaraan, Bandung, 2013.

[4] D. Appleyard, "Renewable Energy World," 1 6 2009. [Online]. Available: http://www.renewableenergyworld.com/rea/news/article/2009/06/solar-trackers-facing-the-sun. [Accessed 3 12 2013].

[5] M. A. Kadam and S. Garg, "Exploring Regions of Application of Single and Double Axis Solar Tracking Systems," in International Conference on Advances in Mechanical Engineering, Gujarat, 2009.

[6] "Bloodshed Dev-C++," [Online]. Available: http://www.bloodshed.net/devcpp.html. [Accessed 5 January 2013].

[7] Astronomical Applications Department of the U.S. Naval Observatory, "Astronomical Applications Department," 22 April 2013. [Online]. Available: http://aa.usno.navy.mil/data/docs/AltAz.php. [Accessed 2 May 2013].

[8] Australian Government, Geoscience Australia, "Geoscience Australia," 24 November 2011. [Online]. Available: http://www.ga.gov.au/geodesy/astro/smpos.jsp#intzone. [Accessed 2 May 2013].

[9] "Wikimapia," [Online]. Available: http://wikimapia.org/4034159/id/Kompleks-LIPI. [Accessed 11 10 2013].

[10] R. Anugraha, February 2012. [Online]. Available: http://rinto.staff.ugm.ac.id/wp-content/uploads/Mekanika-benda-langit-Rinto-Anugraha.pdf. [Accessed 5 January 2013].

[11] "GMT: Greenwich Mean Time - World Time / Time in every Time Zone," 2013. [Online]. Available: http://wwp.greenwichmeantime.com/. [Accessed 5 January 2013].